Decoding Phonological Working Memory For Non-Words and Real Words

Statement of problem

Reading relies on phonological and semantic working memory (Caplan & Waters, 1999). Separating the effects of load in either system would be important for understanding how we read. For example, when reading becomes difficult due to either the text or the reader, what systems must the reader rely upon to persevere?

Literature review

It has been shown in the literature that phonological working memory loads recruit cortical resources in areas associated with speech perception such as superior temporal cortex(STC) and speech production such as the left dorsolateral prefrontal cortex as well as the supplemental motor area(SMA) and inferior frontal gyrus(IFG)(Perrachione et al. 2017). Both the SMA and IFG has been shown to be active during phonological working memory. The process that underlies phonological working memory has been described as "auditory rehearsal"(Jacquemot and Scott, 2006). The auditory rehearsal process underlying phonological working memory has been represented in the SMA during encoding of nonword stimuli(Hartwigsen et al. 2013).

One recently popularized method used to analyze the efficacy of working memory systems is to decode brain signals in order to verify that information that is relevant to the encoded item is available during the period when memory rehearsal is thought to occur. Brain frequencies, particularly alpha have been used by decoding methods (Foster, Bsales, Jaffe & Awh, 2017). Bonnefond & Jensen, (2012) were able to show connect between alpha synchrony in MEG and the successful recovery of a memory trace in the face of distractors. Foster et al., 2017, were able to use alpha frequency of the EEG during a delay period to decode the location (on the screen) of items held in memory.

Decoding methods have been used to probe language stimuli held in memory. Using EEG, LaRocque, Joshua J. et al., (2013) were able to use a supervised classifier to decode the stimulus category (pseudowords, words, and lines) during a delay interval, that is, while the stimuli were not presented and held in working memory. Despite their success in testing their hypothesis (about how attention and working memory interact), these authors did not determine which frequencies in the signal, nor locations of activity, were best able to classify the items.

Hypotheses:

1. We hypothesize that more phonologial working memory processes will recruit the STG, IFG and SMA cortical regions during processing of the nonwords when compared to real words.
2. We will successfully (>33%) be able to classify the memory load associated with the number of syllables in the study set.
3. If phonological/motor working memory processes are easier to decode than semantic processes, then our successful classification of the study set difficulty will be easier for pseudowords than for words.

Participants and Materials:
5-8 participants ages 18 or older. Native English Speakers.
2(word vs pseudo) X 3 (1,2,3 syllables) design. There will be 6 study list conditions.

There will be two conditions(words/nonwords). Study sets will consist of three words, or three pronounceable nonwords. In addition to word/nonword factor, we will also have 3 levels of syllable length(1-3 syllables). Each of the three items in the study set will be the same syllable length, 1, 2 or three syllables See (Table 1). There will be twenty five study sets for each condition.

Procedure

Each trial will begin with a fixation cross (~1 second), followed by a screen displaying a study list of three words for 5 seconds. After the study list, a new fixation cross will appear for 5 seconds (Delay period). Participants will be instructed to center their gaze on the fixation cross during this time. After the delay period, a probe word will be presented. Participants will have 2 seconds to judge whether the probe word matches a word seen previously in the study list, and will be asked to indicate their response with a button press (1 for "yes", 2 for "no").

Fixation:1 seconds
Display:5 seconds
Delay: 5 seconds
Test: 2 seconds
ITI: 2 seconds

Memory load

Syllables	Pseudoword	Word
1	ik, gog, koh	rum, dog, sand
2	uba, nibo, clar	kitten, digging, fishing
3	tibumpa, galutino, haruby	listening, satellite, patella

Table 1.
Green= easy
Orange=moderate
Red= hard

Analysis

The data will be processed using MATLAB or Python. The sensor signals are pre-processed to remove noise caused by muscle or eye movement. As we would like to decode word/nonword and number of syllables from frequency pattern of signals, we first localize the brain region from where we observe maximum activity and then consider corresponding MEG sensor signals for decoding. Source localization would help us to filter out the sensors which are not corresponding to activity and minimizes the processing effort. The filtered sensory signals are passed through Fourier transform extract frequency components and power associated with it. The frequency components of each task act as the features for pattern classification analyses. We plan to use supervised classification algorithm similar to LaRocque, Joshua J. et al., (2013).

References

Bonnefond, M., & Jensen, O. (2012). Alpha oscillations serve to protect working memory maintenance against anticipated distracters. *Current biology*, *22*(20), 1969-1974.

Buchsbaum, B. R., Baldo, J., Okada, K., Berman, K. F., Dronkers, N., D'Esposito, M., & Hickok, G. (2011). Conduction aphasia, sensory-motor integration, and phonological short-term memory–an aggregate analysis of lesion and fMRI data. *Brain and language*, *119*(3), 119-128.

Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *Behavioral and brain Sciences*, *22*(1), 77-94.

Foster, J. J., Bsales, E. M., Jaffe, R. J., & Awh, E. (2017). Alpha-band activity reveals spontaneous representations of spatial position in visual working memory. *Current Biology*, *27*(20), 3216-3223.

Hartwigsen, G., Saur, D., Price, C. J., Baumgaertner, A., Ulmer, S., & Siebner, H. R. (2013). Increased facilitatory connectivity from the pre-SMA to the left dorsal premotor cortex during pseudoword repetition. *Journal of Cognitive Neuroscience*, 25, 580–594.

Jacquemot, C.,Scott, S.K. 2006. What is the relationship between phonological short-term memory and speech processing? *Trends in Cognitive Science* 10(11), 480-486.

Separability of active semantic and phonological maintenance in verbal working memory
Nishiyama R (2018) Separability of active semantic and phonological maintenance in verbal working memory. PLOS ONE 13(3): e0193808. https://doi.org/10.1371/journal.pone.0193808

Tyler K. Perrachione TK, Satrajit, SG S. Ghosh, Ostrovskaya I, Gabrieli J.D.E, Kovelmana, I.(2017). Phonological working memory for words and nonwords in cerebral cortex. *Journal of Speech and Hearing Research,*60 1959-79.

LaRocque, Joshua J. et al. "Decoding Attended Information in Short-Term Memory: An EEG Study." *Journal of cognitive neuroscience* 25.1 (2013): 127–142. *PMC*. Web. 10 Mar. 2018.